10 Gulf of Alaska Pelagic Shelf Rockfish

(Executive Summary)

by
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10.0 Introduction

For 2005, GOA rockfish have been moved to a biennial stock assessment schedule to coincide with new survey data. On alternate (even) years we will present an executive summary with last year's harvest parameters and projection for this year, and this year's harvest parameters and projection for next year with updated catch information. Last year's full stock assessment is on the web (Clausen et al. 2003, http://www.afsc.noaa.gov /refm/docs/2003/GOApsrock.pdf). The 2003 pelagic shelf rockfish assessment also contains the results of an age-structured model for dusky rockfish (Lunsford et al. 2003, http://www.afsc.noaa.gov/refm/docs/2003/GOAdusky.pdf).

We note that the forms of dusky rockfish commonly recognized as "light dusky rockfish" and "dark dusky rockfish" are now officially recognized as two species (Orr and Blackburn 2004). *Sebastes ciliatus* applies to the dark shallow-water species with a common name dark rockfish, and *S. variabilis* applies to variably colored deeper-water species with a common name dusky rockfish.

In 2003 for dusky rockfish, the age-structured model was first accepted as an alternative to average trawl survey biomass estimates and was used to determine the ABC. For yellowtail, dark, and widow rockfishes we continue to recommend using the average of exploitable biomass from the 1999, 2001, and 2003 trawl surveys to determine the ABC's.

For dusky rockfish, we continue to use the generic rockfish model as the primary assessment tool. This model was developed in a workshop held at the Auke Bay Laboratory in February 2001, and refined to its current configuration in 2004. The model was constructed with AD Model Builder software. The model is a separable age-structured model with allowance for size composition data that is adaptable to several rockfish species. The model's starting point is 1977 and contains all available data including catch, fishery age and size compositions, survey age and size compositions, and survey biomass estimates.

10.1 Summary of Major Changes

There are no major changes in the Pelagic Shelf assessment for yellowtail, dark, and widow rockfishes for 2005. This is because no new survey data has become available since the 2004 assessment. The same values of current exploitable biomass, ABC, ABC geographic apportionment, and overfishing are recommended for 2005 as were recommended for 2004. The 2005 recommended ABC for yellowtail, widow, and dark rockfish combined is 497 mt. The OFL (F=M=0.09) for yellowtail, widow, and dark rockfish is 663 mt.

For dusky rockfish, substantial refinements were made to last year's assessment because new age data became available this year (Appendix A). This year's model includes new age data for the 2000 and 2002 fishery, and the 2003 survey. Also, larger sample sizes of ages became available for the 1987 and 2001 surveys and were added to the model. Other new data in the model include

2004 fishery lengths, the updated 2003 fishery catch (3,048 mt) and an estimated 2004 fishery catch (2,651 mt). The new age data from both the survey and the fishery support the strength of the 1987 and 1992 year classes. The 2003 survey ages indicate the 1995 and 1997 year classes are above average, but these year classes are not yet evident in the fishery age data.

For this year we recommend an alternative model to the one presented last year. Three alternative models are presented in Appendix A including the base model used in 2004. The recommended model reduces the weight on fishery catch from 100 to 10 and increases the survey biomass weight from one to five. For 2005, the Plan Team encouraged us to explore the historic catches and determine their effect on the model results. In response, catch was down-weighted because we believe the 1985-1987 catches were underestimated because of inaccurate catch accounting during the beginning of the domestic fishery. Survey biomass weight was increased to better fit survey biomass estimates. This was in response to concerns expressed by the Plan Team last year that the fit to survey biomass estimates showed strong positive residuals.

We recommend the new ABC of 4,056 mt from the revised model accepted for 2004 for use in the 2005 fishery. This ABC is similar to last year's ABC of 4,001 mt. The corresponding reference values for dusky rockfish are summarized below. The stock is not overfished, nor is it approaching overfishing status. The primary reference values are shown in the following table, with the recommended values in bold.

Dusky Rockfish Summary Table	Last year's projection Not Updated		This year's projection Revised Model	
	2004	2005	**2005**	2006
$B_{40\%}$ (mt)	14,280	14,280	**14,300**	14,300
Female Spawning Biomass (mt)	16,157	14,749	**17,766**	16,427
$F_{50\%}$	0.082	0.082	0.080	0.080
F_{ABC} (maximum allowable=$F_{40\%}$)	0.123	0.123	**0.120**	0.120
F_{OFL} ($F_{35\%}$)	0.153	0.153	**0.148**	0.148
$ABC_{F50\%}$	2,667	2,371	2,718	2,625
$ABC_{F40\%}$ (mt; maximum allowable)	4,001	3,557	**4,056**	3,918
OFL(mt, $F_{35\%}$)	4,900	4,400	**5,018**	4,832

10.2 Area Allocation

Apportionment is based on the Plan Team's recommendation of weighting of the surveys at 4:6:9 (for 1999, 2001, and 2003). The apportionment percentages are identical to last year, because there is no new survey information. The following table shows the recommended apportionment of Pelagic Shelf Rockfish for 2005 combining the new model results for dusky rockfish and the same results as last year's assessment for other pelagic rockfish.

Pelagic shelf rockfish apportionment				
Year	Western Gulf	Central Gulf	Eastern Gulf	Total
Area Apportionment	8%	67%	24%	100%
Area ABC (mt) *Dusky Rockfish*	336	2,732	988	4,056
Area ABC (mt) *Yellowtail, Dark, Widow Rockfish*	41	335	121	497
Total ABC 2005 (mt)	**377**	**3,066**	**1,109**	**4,553**
Total ABC 2006 (mt)	**366**	**2,973**	**1,076**	**4,415**
Total OFL 2005 (mt)	471	3,826	1,384	5,680
Total OFL 2006 (mt)	457	3,711	1,343	5,510

Amendment 41 prohibited trawling in the Eastern area east of 140° W longitude. The ratio of biomass still obtainable in the W. Yakutat area (between 147° W and 140° W) is the same as last year at 0.19. This results in an apportionment to the W. Yakutat area of 211 mt, which would leave 898 mt unharvested in the Eastern Gulf.

10.3 Responses to SSC Comments

There were no comments from the SSC specifically directed towards the GOA pelagic shelf rockfish assessment in last year's SAFE.

10.4 Responses to Plan Team Comments

The Plan Team requested that the authors explore estimation of historic catches as this could explain some of the signals in the data. In 2004 we determined the catch was likely underestimated in the years 1985-1987. These catches occurred during the end of the joint venture years and prior to accurate catch accounting of the newly formed domestic fishery. In the author recommended model we reduced the weight on fishery catch from 100 to 10 since those years may be skewing the data.

The Plan Team was concerned about fit to survey biomass estimates in last year's model because it showed strong positive residuals to these estimates. In the author recommended model we increased the model weighting of survey biomass weight from one to five to better fit survey biomass estimates.

Appendix 10A: Dusky Rockfish Age-Structured Model

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10A.0 Overview

For dusky rockfish (*Sebastes variabilis*), we explored the use of a generic rockfish model developed in a modeling workshop held at the Auke Bay Laboratory in February 2001[1]. The model was constructed with AD Model Builder software (Otter Research Ltd 2000). The model is a separable age-structured model with allowance for size composition data that is adaptable to several rockfish species. In 2002, we presented a working base model which incorporated all of the available dusky rockfish data and provided reasonable fits to the data. In 2003, we made substantial refinements to the base model and began using the model to recommend an ABC. This model was based on limited amounts of age data. In 2004 a substantial amount of new age data became available for dusky rockfish. While most Gulf of Alaska rockfish species are moving to biennial assessments, we have again revised the dusky rockfish model for 2004 because of some concerns over last year's model and the addition of new age data.

10A.1 Data

10A.1.1 Fishery Data

10A.1.1.1 Catch

Catch estimates are a combination of foreign observer data, joint venture catch data, and NMFS Regional Office blend data. Catches range from 17 mt in 1986 to 4538 mt in 1999. We are skeptical of the low catches that occurred prior to 1988 and believe the catches for years 1985-1987 are likely underestimated. (Table 10A-1, Figure 10A-1). These catches occurred during the end of the joint venture years and prior to accurate catch accounting of the newly formed domestic fishery.

10A.1.1.2 Age Composition

Observers aboard fishing vessels and at onshore processing facilities have provided data on size and age compositions of the commercial catch of dusky rockfish. The fishery age data depicts the simple raw age distribution of the samples, and we did not attempt any further analysis to estimate a more comprehensive age composition. For the 2003 model, fishery ages were only available for 2001. In 2004, 854 new fishery ages became available from 2000 and 2002 and are incorporated in the 2004 model (Table 10A-2). Several large and relatively steady year classes are evident through the time series (Figure 10A-4). All three years accurately track the 1987 year class which shows up as 13 year olds in 2000 and the 1992 year class which is evident as eight year olds in 2000.

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[1]Rockfish Modeling Workshop, NMFS Auke Bay Laboratory, 11305 Glacier Hwy., Juneau, AK, February, 2001.

10A.1.1.3 Size Composition

Size compositions from the fishery are used for 1990-1999, 2003, and 2004 (Table 10A-3, Figure 10A-5). The reader is cautioned that for each year, these data are the raw length frequencies for all dusky rockfish measured by observers. There was no attempt to collect or analyze these data systematically, and some biases may be expected, especially for 1995 and 1996 when sample sizes were relatively small. Generally, however, these lengths were taken from hauls in which dusky rockfish were either the target or a dominant species, and they provide an indication of the trends in size composition for the fishery. Fishery lengths from 2000-2002 are not used in the model because ages are available for those years.

10A.1.2 Survey Data

10A.1.2.1 Biomass Estimates

Comprehensive trawl surveys were conducted on a triennial basis in the Gulf of Alaska in 1984, 1987, 1990, 1993, 1996, and 1999, and these surveys became biennial in 2001 and 2003. The 2001 survey biomass is a weighted average of 1993-1999 biomass estimates, since the Eastern Gulf was not surveyed. Comparative biomass estimates for the eight triennial surveys show wide fluctuations for dusky rockfish (Table 10A-4, Figure 10A-2). Total estimated biomass increased substantially between 1984 and 1987, dropped by over 50% in 1990, rebounded in 1993 and 1996, and decreased again in 1999 and 2001 (in areas that were sampled in 2001), and then increased in 2003. Large confidence intervals are associated with all these biomass estimates, particularly in 1987, 1996, and 2003, and are an indication of the generally patchy and highly aggregated distribution of this species. Whether these fluctuations indicate true changes in abundance, a temporal changes in the availability of dusky rockfish to the survey gear, or are an artifact of the imprecision of the survey for this species, is unknown. However, because of the apparently light fishing pressure on dusky rockfish during most of these years (catches have usually been much less than the ABC), and their relatively low rate of natural mortality, large and abrupt changes in abundance such as those shown by the trawl surveys seem unlikely. Surveys with the larger biomass estimates do not influence the model as much as lower, more precise estimates because of the high imprecision surrounding the larger biomass estimates.

10A.1.2.2 Age Composition

Survey age compositions from the 1984 through 2003 trawl surveys are used in the model (Table 10A-5, Figure 10A-6). In general, samples sizes were small. In 2004 additional ages became available for the 1987 and 2001 surveys. Ages from the 2003 survey were also completed in 2004. For each survey, ages were determined using the “break-and-burn” method of aging otoliths, and a Gulfwide age-length key was developed. The key was then used to estimate age composition of the dusky rockfish population in the Gulf of Alaska. The 1976 year class appeared to be abundant in the 1984 survey. This year class is also prominent in the 1987 and 1990 age compositions. In 1987, just 4 year classes (1975, 1976, 1977, and 1980) comprised over 75% of the estimated population, and mean age was 10.5 years. The 1990 results showed no significant recruitment of young fish and appeared to merely reflect growth of the population that existed in 1987; mean age was 14.4 years. The 1993 age composition showed a very prominent 1986 year class. This year class is clearly associated with the large influx of small fish in the 1993 size compositions, and its presence likely explains much of the increase in dusky rockfish biomass that year. The existence of a strong 1986 year class was further confirmed by the 1996 age composition, in which this year class was again the most important. The 1996 results showed little evidence of recruitment of young fish <10 years old; accordingly, mean age of the population increased from 12.1 years in 1993 to 14.7 years in 1996. In 1999, fish <10 years old again comprised only a small part of the population, and fish aged 12, which would correspond to the 1987 year class, were very prominent. The 2001 age compositions showed the 1987 year class was still discernable as a distinct mode at age 14 and the 2003 age compositions showed a distinct mode at age 16. Because rockfish are difficult to age, especially as they get older, and perhaps some of the fish have been categorized into adjacent age classes between surveys it's likely the 1993 and 1996 survey compositions were really tracking the 1987 year class instead of 1986. The 2001 data also indicated a possibly strong 1992 year class and that very few fish were >16 year old. The 2003 survey ages track the 1987 and 1992 year classes but they are overshadowed by the 1995 (eight year old fish) and 1997 (six year old fish) year classes. The low proportion of older fish in 2003 may be a function of the dominant 1995 year class and is an indication of strong recruitment in recent years. Finally, the fishery age distributions discussed previously in section 10.3.1 agree with these survey age compositions, as they all show prominent 1987 and 1992 year classes. However, the fishery data shows no sign of the 1995 and 1997 year classes in 2002 despite the fact these year classes dominate the 2003 survey ages. This is likely due to an older age of selection for the fishery.

10A.1.2.3 Size Composition

Gulfwide survey size compositions are available from 1984-2003 (Table 10A-6). Survey size compositions suggest that recruitment of dusky rockfish is a relatively infrequent event, as only two surveys, 1993 and 2003, showed evidence of substantial recruitment (see Clausen and Heifetz 1989 for 1987 results and Table 10A-6 for 1990 through 2003 results). Mean population length increased from 39.8 cm in 1987 to 43.1 cm in 1990, apparently the result of growth. In 1993, however, a large number of small fish (~27-35 cm long) appeared which formed a sizeable percentage of the population, and this recruitment decreased the mean length to 38.3 cm. In the 1996 and 1999 surveys, the length frequency distribution was similar to that of 1990, with very few small fish, and both years had a mean population length of 43.9 cm. The 2001 size composition, although not directly comparable to previous years because the eastern Gulf of Alaska was not sampled, shows modest recruitment of fish <40 cm. In 2003, a distinct mode of fish is seen at ~30 cm that suggests relatively strong recruitment may be occurring. Survey size compositions are not used in the model because survey ages are used from those same years in the model and in the construction of the size-age matrix.

10A.2 Analytic Approach

10A.2.1 Model Structure

We present model results for dusky rockfish based on an age-structured model using AD Model Builder software (Otter Research Ltd 2000). In 2003, the stock assessment was first accepted as an alternative to trawl survey biomass estimates. The assessment model is now based on a generic rockfish model developed in a workshop held in February 2001[1] and follows closely the GOA Pacific ocean perch model (Hanselman et al. 2003). The main difference between the dusky model and the Pacific ocean perch model is that natural mortality is not estimated in the dusky rockfish model. This model is similar to other models used by the AFSC (Alaska Fisheries Science Center) with the exception that this model does not attempt to fit a stock-recruitment relationship but estimates a mean recruitment, which is adjusted by estimated recruitment deviations for each year. We do this because there does not appear to be an obvious stock-recruitment relationship in the model estimates, and there is no information on low spawners and low recruits (Figure 10A-3). The parameters, population dynamics and equations of the model are in Box 1.

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[1]Rockfish Modeling Workshop, NMFS Auke Bay Laboratory, 11305 Glacier Hwy., Juneau, AK, February, 2001.

10A.2.2 Parameters Estimated Independently

Life-history parameters including natural mortality (*M*), proportion mature at age, and weight at age, were taken from the 2001 Pelagic Shelf Rockfish SAFE Document (Clausen and Heifetz, 2001). Clausen and Heifetz (1999) presented revised estimates of the von Bertalanffy growth parameters for combined sexes of dusky rockfish. These were based on age samples from 1,245 fish in the 1984, 1987, 1990, and 1993 triennial surveys. The revised parameters are: L_{inf} = 45.9 cm; k = 0.24; and t_o = 1.18. A recent manuscript has also been prepared that presents these results in more detail (Malecha et al. 2004).

The best length-weight information for light dusky rockfish comes from the 1996 triennial survey, in which motion-compensated electronic scales were used to weigh a relatively large sample of individual fish for this species. For combined sexes, using the formula $W = aL^b$, where W is weight in grams and L is fork length in mm, a = 3.28×10^{-5} and b = 2.90 (Martin 1997).

Size at 50% maturity for a relatively small sample (n=64) of female light dusky rockfish in the Kodiak area has been estimated to be 42.8 cm fork length (Clausen and Heifetz 1997). Age data for these fish were analyzed using a logistic function, which provided an estimated age at 50% maturity of 11.3 years[2].

The size-age transition matrix came from a lognormal fit to the Von Bertalanffy growth curve to length and age data collected from triennial trawl surveys with parameter estimates from Malecha et al. (2004). Aging error matrices were constructed by assuming that the break-and-burn ages were unbiased but had a given amount of normal error around each age. The age error transition matrix was constructed by assuming the same age determination error used for northern rockfish (Courtney et al. 1999).

10A.2.3 Parameters Estimated Conditionally

Parameters estimated conditionally include but are not limited to: catchability, selectivity (up to full selectivity) for surveys and fishery, recruitment deviations, mean recruitment, fishing mortality, and spawners per recruit levels. Other model parameters are described in Box 1.

10A.2.4 Uncertainty

Evaluation of model uncertainty has recently become an integral part of the “precautionary approach” in fisheries management. In complex stock assessment models such as this model, evaluating the level of uncertainty is difficult. One way is to examine the standard errors of parameter estimates from the Maximum Likelihood (ML) approach derived from the Hessian matrix. While these standard errors give some measure of variability of individual parameters, they often underestimate their variance and assume that the joint distribution is multivariate normal. An alternative approach is to examine parameter distributions through Markov Chain Monte Carlo (MCMC) methods (Gelman et al. 1995). When treated this way, our stock assessment is a large Bayesian model, which includes informative (e.g., lognormal natural mortality with a small CV) and noninformative (or nearly so, such as a parameters bounded between 0 and 10) prior distributions. In the models presented in this SAFE report, the number of parameters estimated is 125. In a low-dimensional model, an analytical solution might be possible, but in one with this many parameters, an analytical solution is intractable. Therefore, we use MCMC methods to estimate the Bayesian posterior distribution for these parameters. The

[2] C. Lunsford, National Marine Fisheries Service, Alaska Fisheries Science Center, Auke Bay Laboratory, 11305 Glacier., Juneau, AK 99801. Pers. commun. August 1999.

basic premise is to use a Markov chain to simulate a random walk through the parameter space which will eventually converge to a stationary distribution which approximates the posterior distribution. Determining whether a particular chain has converged to this stationary distribution can be complicated, but generally if allowed to run long enough, the chain will converge (Jones and Hobert 2001). The "burn-in" is a set of iterations removed at the beginning of the chain. This method is not strictly necessary, but we use it as a precautionary measure (Gelman et al. 1995). In our simulations we removed the first 50,000 iterations out of 5,000,000 and "thinned" the chain to one value out of every thousand, leaving a sample distribution of 4,950. We compared running means of the chain, examined autocorrelation and examined traces of the chains after removing the "burn-in" and "thinning". We believe that convergence to the posterior distribution was likely if a long chain was used without encountering obvious problems in diagnostic plots. We used these MCMC methods to provide further evaluation of uncertainty in the results below.

BOX 1. AD Model Builder Model Description

Parameter definitions	
y	Year
a	Age classes
l	Length classes
w_a	Vector of estimated weight at age, $a_0 \rightarrow a_+$
m_a	Vector of estimated maturity at age, $a_0 \rightarrow a_+$
a_0	Age at first recruitment
a_+	Age when age classes are pooled
μ_r	Average annual recruitment, log-scale estimation
μ_f	Average fishing mortality
σ_r	Annual recruitment deviation
ϕ_y	Annual fishing mortality deviation
fs_a	Vector of selectivities at age for fishery, $a_0 \rightarrow a_+$
ss_a	Vector of selectivities at age for survey, $a_0 \rightarrow a_+$
M	Natural mortality, fixed
$F_{y,a}$	Fishing mortality for year y and age class a ($fs_a \mu_f e^{\varepsilon}$)
$Z_{y,a}$	Total mortality for year y and age class a ($=F_{y,a}+M$)
$\varepsilon_{y,a}$	Residuals from year to year mortality fluctuations
$T_{a,a'}$	Aging error matrix
$T_{a,l}$	Age to length transition matrix
q	Survey catchability coefficient
SB_y	Spawning biomass in year y, ($=m_a\, w_a\, N_{y,a}$)
q_{prior}	Prior mean for catchability coefficient
$\sigma_{r(prior)}$	Prior mean for recruitment deviations
σ_q^2	Prior CV for catchability coefficient
$\sigma_{\sigma_r}^2$	Prior CV for recruitment deviations

BOX 1 (Continued)

Equations describing the observed data

$$\hat{C}_y = \sum_a \frac{N_{y,a} * F_{y,a} * \left(1 - e^{-Z_{y,a}}\right)}{Z_{y,a}} * w_a$$

Catch equation

$$\hat{I}_y = q * \sum_a N_{y,a} * \frac{s_a}{\max(s_a)} * w_a$$

Survey biomass index (mt)

$$\hat{P}_{y,a'} = \sum_a \left(\frac{N_{y,a} * s_a}{\sum_a N_{y,a} * s_a} \right) * T_{a,a'}$$

Survey age distribution
Proportion at age

$$\hat{P}_{y,l} = \sum_a \left(\frac{N_{y,a} * s_a}{\sum_a N_{y,a} * s_a} \right) * T_{a,l}$$

Survey length distribution
Proportion at length

$$\hat{P}_{y,a'} = \sum_a \left(\frac{\hat{C}_{y,a}}{\sum_a \hat{C}_{y,a}} \right) * T_{a,a'}$$

Fishery age composition
Proportion at age

$$\hat{P}_{y,l} = \sum_a \left(\frac{\hat{C}_{y,a}}{\sum_a \hat{C}_{y,a}} \right) * T_{a,l}$$

Fishery length composition
Proportion at length

Equations describing population dynamics

Start year

$$N_a = \begin{cases} e^{\left(\mu_r + \tau_{styr - a_0 - a - 1}\right)}, & a = a_0 \\ e^{\left(\mu_r + \tau_{styr - a_0 - a - 1}\right)} e^{-(a - a_0)M}, & a_0 < a < a_+ \\ \dfrac{e^{(\mu_r)} e^{-(a - a_0)M}}{\left(1 - e^{-M}\right)}, & a = a_+ \end{cases}$$

Number at age of recruitment

Number at ages between recruitment and pooled age class

Number in pooled age class

Subsequent years

$$N_{y,a} = \begin{cases} e^{\left(\mu_r + \tau_y\right)}, & a = a_0 \\ N_{y-1,a-1} * e^{-Z_{y-1,a-1}}, & a_0 < a < a_+ \\ N_{y-1,a-1} * e^{-Z_{y-1,a-1}} + N_{y-1,a} * e^{-Z_{y-1,a}}, & a = a_+ \end{cases}$$

Number at age of recruitment

Number at ages between recruitment and pooled age class

Number in pooled age class

Formulae for likelihood components **BOX 1 (Continued)**

$$L_1 = \lambda_1 \sum_y \left(\ln\left[\frac{C_y + 0.01}{\hat{C}_y + 0.01} \right] \right)^2$$

Catch likelihood

$$L_2 = \lambda_2 \sum_y \frac{\left(I_y - \hat{I}_y\right)^2}{2 * \hat{\sigma}^2 \left(I_y\right)}$$

Survey biomass index likelihood

$$L_3 = \lambda_3 \sum_{styr}^{endyr} -n^*{}_y \sum_a^{a+} \left(P_{y,a} + 0.001\right) * \ln\left(\hat{P}_{y,a} + 0.001\right)$$

Fishery age composition likelihood ($n^*{}_y$ =square root of sample size, with the largest set to one hundred)

$$L_4 = \lambda_4 \sum_{styr}^{endyr} -n^*{}_y \sum_l^{l+} \left(P_{y,l} + 0.001\right) * \ln\left(\hat{P}_{y,l} + 0.001\right)$$

Fishery length composition likelihood

$$L_5 = \lambda_5 \sum_{styr}^{endyr} -n^*{}_y \sum_a^{a+} \left(P_{y,a} + 0.001\right) * \ln\left(\hat{P}_{y,a} + 0.001\right)$$

Survey age composition likelihood

$$L_6 = \lambda_6 \sum_{styr}^{endyr} -n^*{}_y \sum_l^{l+} \left(P_{y,l} + 0.001\right) * \ln\left(\hat{P}_{y,l} + 0.001\right)$$

Survey size composition likelihood

$$L_7 = \frac{1}{2\sigma_q^2} \left(\ln \frac{q}{q_{prior}} \right)^2$$

Penalty on deviation from prior distribution of catchability coefficient

$$L_8 = \frac{1}{2\sigma_{\sigma_r}^2} \left(\ln \frac{\sigma_r}{\sigma_{r(prior)}} \right)^2$$

Penalty on deviation from prior distribution of recruitment deviations

$$L_9 = \lambda_9 \left[\frac{1}{2 * \sigma_r^2} \sum_y \tau_y^2 + n_y * \ln\left(\sigma_r\right) \right]$$

Penalty on recruitment deviations

$$L_{10} = \lambda_{10} \sum_y \phi_y^2$$

Fishing mortality regularity penalty

$$L_{11} = \lambda_{11} \bar{s}^2$$

Average selectivity penalty (attempts to keep average selectivity near 1)

$$L_{12} = \lambda_{12} \sum_{a_0}^{a_+} \left(s_i - s_{i+1}\right)^2$$

Selectivity dome-shapedness penalty – only penalizes when the next age's selectivity is lower than the previous (penalizes a downward selectivity curve at older ages)

$$L_{13} = \lambda_{13} \sum_{a_0}^{a_+} \left(FD(FD(s_i - s_{i+1}) \right)^2$$

Selectivity regularity penalty (penalizes large deviations from adjacent selectivities by adding the square of second differences

$$L_{total} = \sum_{i=1}^{13} L_i$$

Total objective function value

10A.3 Model Evaluation

10A.3.1 Alternative Models

10A.3.1.1 Model 1: Base model with updated catches

This model was the base model that was presented in the 2003 Pelagic Shelf Rockfish assessment and accepted to determine the 2004 ABC. It was nearly identical to the Pacific ocean perch assessment (Hanselman et al. 2003) except that natural mortality was held fixed. In Model 1 we kept the model the same and updated the catches for 2003 and 2004 (Figure 10A-2).

10A.3.1.2 Model 2: Model 1 with new age and length data, updated catches, and reduced catch weight

In 2004 a significant portion of new length and age data became available from both the survey and fishery. Model 2 incorporates the new catch, age, and length data (Figure 10A-2). As recommended by the Plan Team, we examined the catch data and determined it to be unrealistic in the earlier part of the time series for the years 1985-1987. The extremely low catches reported for these years were disproportionate to Pacific ocean perch and northern rockfish catch data, which is unlikely since dusky rockfish are generally caught as bycatch during these two fisheries (Ackley and Heifetz 2001). The estimates were likely the result of poor catch accounting at the inception of the domestic fishery. These low catches were found to influence the model more than previously thought. We, therefore, lowered the catch weight from 100 to 10 to put less emphasis on the earlier time series of catches.

10A.3.1.3 Model 3: Model 2 with survey biomass given higher weight

Some concerns were raised by the Plan Team in the 2003 model regarding fit to survey biomass estimates. Last year's model showed strong positive residuals to these estimates. This model is identical to Model 2 except that we increase the survey biomass data weighting from one to five, to better fit the survey biomass estimates (Figure 10A-2).

10A.3.2 Model Comparison

We compared stock assessment results for the three different model configurations. Table 10A-7 summarizes results from all three models. Parameter estimates for Models 1 and 3 were fairly similar overall, except for total biomass and ABC using $F_{40\%}$ which was larger in Model 3. Alternatively, Model 2 indicated a large drop in most of the biomass estimates, particularly for $B_{40\%}$ and ABC using $F_{40\%}$. Objective functions were comparable for Models 2 and 3 since the same amount of data was used in these models, and these values were similar (Table 10A-7).

We expected model estimates of survey biomass to be only slightly influenced by the large yet highly variable estimates of the 1987, 1996, and 2003 surveys. Model fits to the survey biomass estimates were similar between Models 1 and 2, both generally flat with a downward trend in the most recent years indicating a stable or slightly decreasing population. Survey biomass residuals in these two models were primarily positive (Figure 10A-2). Model 3 did a better job of fitting the most recent survey biomass estimates than the other models. The trend was similar to Models 1 and 2 in the early years, then increased slightly and stabilized in the most recent years indicating a relatively stable population overall (Figure 10A-2).

10A.3.3 Model Results

Models 2 and 3 make use of the most recent age and length data available, and we present estimates of total and spawning biomass for these two scenarios. Model 1 biomass estimates were similar to last year's assessment. A positive skew of predicted values was expected in all models because a wider range of high values occurs in a lognormally distributed population. However, in the most recent years, total and spawning biomass estimates for Model 2 fell along the lower 95% confidence interval estimated from the 5 million MCMC runs (Figures 10A-7 and 10A-8). Model 3 estimates were more consistent with the predicted values falling between the 95% confidence bounds (Figures 10A-9 and 10A-10).

The higher weighting on the survey biomass data in Model 3 may have reduced the effect of the discrepancies between the new fishery and survey age data. Most of the new data in Models 2 and 3 were 2000 and 2001 fishery ages and 2003 survey age compositions. The observed fishery age data was dominated by large proportions from two distinct older age classes that could be easily tracked throughout the three available years of age data (Figure 10A-4). No strong recruitment is evident in the fishery ages following the 1992 year class. Observed fishery length data was also fairly consistent across years with a larger proportion of larger sized fish in the most recent years (Figure 10A-5). The new 2003 survey age data was dominated by a large proportion of eight year-old fish (1995 year class) and to a lesser extent six year old fish (1997 year class) that may have masked the presence of the older year classes that were predominant in the fishery data (Figure 10A-6). These fish also show up in the 2003 survey lengths where there is a distinct mode of fish at ~30cm. The presence of the 1995 and 1997 year classes in the survey data but not in the fishery ages may be the source of the inconsistencies between Model 2 and Model 3. Increasing the weight of the survey biomass in Model 3 may help explain why the total and spawning biomass estimates from Model 2 fell along the lower end of the 95% confidence interval but improved in Model 3 estimates.

Model 3 predictions for the fishery age and length compositions were fairly consistent with the observed data (Figure 10A-4 and 10A-5) even though this model increased the weighting on the survey biomass data. Trawl survey age compositions were also estimated well by Model 3 with a less emphasized peak of the younger fish (i.e.,eight year-old fish) in the 2003 data (Figure 10A-6). Model 3 results in slightly larger ABC than Model 1 which was the updated last year's model without new age and length data (Table 10A-7). In other models increases in the biomass estimates are often due to the model altering the selectivity curves to decrease after a certain age (i.e., dome shaped selectivity). This suggests that older fish exist but are less subject to fishing pressure due to gear avoidance (i.e. deep depths or hiding in untrawlable habitat). However, dusky rockfish live in fairly shallow areas and we do not expect older ages to exhibit decreases in the selectivity pattern thus we fixed selectivity to be asypmtotic.

The estimated selectivity curves for the fishery and survey data suggested a pattern similar to what we expected for dusky rockfish (Figure 10A-11). The commercial fishery should target larger and subsequently older fish and the survey should sample a larger range of ages given potential gear restrictions. This was supported by the age composition of both the fishery and survey data. Fishery ages were generally from older fish and survey ages were from both younger and older fish (Figures 10A-4 and 10A-6). The age of full recruitment to the fishery and the survey were estimated at 12 and 10, respectively (Figure 10A-11).

We selected the results from Model 3 as the basis for our recommendations for ABC and overfishing because inaccuracies in the historical catch warranted less weight on the catch and increased weighting on the trawl survey biomass estimates improved the model's fit to the biomass estimates. We also recommend continuing to harvest at $F_{40\%}$ since recent evidence suggests that the harvest optimum for Pacific ocean perch in the Gulf of Alaska is between $F_{27\%}$ and $F_{29\%}$ (Hanselman et al. 2004). The new data included in Model 3 also increased confidence (i.e. positive values) in the lower 95% confidence bound on the recruitment estimates in several years (Figure 10A-12). This is a substantial improvement from last year's model especially for the years that are currently being recruited to the fishery and survey (1990-2001) and indicates strong recruitment in recent years.

10A.4 Projections and Harvest Alternatives

10A.4.1 Harvest Alternatives

The management performance path indicates the stock is currently in the 'optimum' quadrant where B_{now}/B_{40} exceeds one and F_{now}/F_{40} is below one (Figure 10A-13). This was not the case for the years prior to 1985 when B_{now}/B_{40} was less than one. The projected 2005 female spawning biomass, B_{2005}, is 17,126 mt. Since B_{2005} is greater than the estimated $B_{40\%}$ value of 14,300 mt, the computation in tier 3a (i.e. $F_{ABC} = F_{40\%}$) is used to determine the maximum value of F_{ABC}. The ABC based on an $F_{40\%}$ harvest rate (0.120) is 4,056 mt (Table 10A-7).

10A.4.2 Model Projections

A standard set of projections is required for each stock managed under Tiers 1, 2, or 3. This set of projections that encompasses seven harvest scenarios is designed to satisfy the requirements of Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2004 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2005 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2004. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2005, are as follows ("max F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

Scenario 1: In all future years, F is set equal to max F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)

Scenario 2: In all future years, F is set equal to a constant fraction of max F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2005 recommended in the assessment to the max F_{ABC} for 2005. (Rationale: When F_{ABC} is set at a value below max F_{ABC}, it is often set at the value recommended in the stock assessment.). The authors do not suggest a proportion of F_{ABC} and do not present this scenario in Table 10A-8.

Scenario 3: In all future years, F is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

Scenario 4: In all future years, F is set equal to the 2000-2004 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be 1) above its MSY level in 2005 or 2) above ½ of its MSY level in 2005 and above its MSY level in 2015 under this scenario, then the stock is not overfished.)

Scenario 7: In 2004 and 2005, F is set equal to max F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2017 under this scenario, then the stock is not approaching an overfished condition.)

10A.4.3 Status Determination

Harvest scenarios #6 and #7 are intended to permit determination of the status of a stock with respect to its minimum stock size threshold (MSST). Any stock that is below its MSST is defined to be overfished. Any stock that is expected to fall below its MSST in the next two years is defined to be approaching an overfished condition. Harvest scenarios #6 and #7 are used in these determinations as follows:

Is the stock overfished? This depends on the stock's estimated spawning biomass in 2004:

a) If spawning biomass for 2005 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b) If spawning biomass for 2005 is estimated to be above $B_{35\%}$, the stock is above its MSST.
c) If spawning biomass for 2005 is estimated to be above ½ $B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest scenario #6 (Table 10A-8). If the mean spawning biomass for 2015 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

Is the stock approaching an overfished condition? This is determined by referring to harvest scenario #7 (Table 10A-8):

a) If the mean spawning biomass for 2007 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.
b) If the mean spawning biomass for 2007 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c) If the mean spawning biomass for 2007 is above ½ $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2017. If the mean spawning biomass for 2017 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

A summary of the results of these scenarios for dusky rockfish is in Table 10A-8. For dusky rockfish the stock is not overfished and is not approaching an overfished condition.

10A.4.4 Area Allocation of Harvests

The geographic apportionment of this ABC was calculated using the same procedure as in previous years, in which prior survey biomass is weighted based on the relative proportion of variability attributed to survey error. This method results in weights of 4:6:9 for the 1999, 2001, and 2003 surveys or 8.3%, 67.3%, and 24.4% of total ABC. The apportionments for 2005 are: Western area, 336 mt, Central area, 2,732 mt, and Eastern area, 988 mt (Table 10A-9). Both the Central and Eastern area are further apportioned into smaller regions. Chirikof (52% of Central area) and Kodiak (48% of Central area) apportionments were 1,430 mt and 1,302 mt, respectively. Amendment 41 prohibited trawling in the Eastern area east of 140° W longitude. The ratio of biomass still obtainable in the W. Yakutat area (between 147° W and 140° W) is the same as last year at 0.19 yielding apportionments of 188 mt for West Yakutat and 800 mt for East Yakutat/Southeast Outside.

10A.4.5 Overfishing Definition

Based on the definitions for overfishing in Amendment 44 in tier 3a (i.e. $F_{OFL} = F_{35\%} = 0.148$), overfishing is set equal to 5,018 mt for dusky rockfish. The overfishing level is apportioned by area for dusky rockfish. Using the apportionment in Section 10A.4.4, results in overfishing levels by area of 416 mt in the Western area, 3,379 mt in the Central area, and 1,223 mt in the Eastern area (Table 10A-9).

10A.5 Summary

The generic rockfish model template using AD Model Builder software has been modified for dusky rockfish. For 2004, weighting on catch and survey biomass estimates were changed and model fits were evaluated. Recommended model results indicate spawning biomass B_{2005} is 17,126 mt which results in an ABC using $F_{40\%}$ of 4,056 mt.

Continued work will be done to improve and refine this model. Dusky rockfish have the least amount of available data of the rockfish species in the GOA that use an age-structured assessment. The addition of the new age data in 2004 improved this model and we hope that we will be able to obtain larger sample sizes of age data in the future. This will allow us to develop an age error transition matrix applicable to dusky rockfish rather than assuming the same age determination error found for northern rockfish. The current sample sizes are too small to be precise for any ages away from the center of the distribution. Improving the data may allow the model to estimate parameters such as natural mortality and recruitment more effectively. MCMC simulations will continue to be used to explore parameter interactions and the distributions of key parameters.

10A.6 Literature Cited

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Table 10A-1. Estimated catch history for dusky rockfish.

Year	Catch
1977	388
1978	162
1979	224
1980	597
1981	845
1982	852
1983	1017
1984	540
1985	34
1986	17
1987	19
1988	1067
1989	1707
1990	1612
1991	2190
1992	3565
1993	3132
1994	2938
1995	2868
1996	2289
1997	2626
1998	3110
1999	4538
2000	3701
2001	3007
2002	3298
2003	3048
2004	2651

Table 10A-2. Fishery age compositions for dusky rockfish in the Gulf of Alaska. Ages are binned below 4 and 21 years and greater.

Age(yr)	2000	2001	2002
4	0.000	0.000	0.000
5	0.000	0.000	0.000
6	0.002	0.002	0.000
7	0.000	0.004	0.007
8	0.012	0.004	0.009
9	0.007	0.043	0.011
10	0.036	0.035	0.104
11	0.048	0.068	0.109
12	0.143	0.077	0.095
13	0.206	0.132	0.064
14	0.211	0.170	0.154
15	0.099	0.161	0.134
16	0.051	0.089	0.120
17	0.027	0.060	0.052
18	0.015	0.031	0.025
19	0.015	0.012	0.011
20	0.012	0.017	0.007
21+	0.116	0.097	0.098
Sample size	413	517	441

Table 10A-3. Fishery size compositions and sample size by year. Lengths below 21 are pooled and ages greater than 47 are pooled.

	Year											
Length (cm)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2003	2004
21	0.214	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22	0.016	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
23	0.011	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24	0.021	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25	0.021	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
26	0.016	0.000	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002
27	0.021	0.000	0.010	0.000	0.000	0.000	0.008	0.000	0.000	0.000	0.000	0.000
28	0.037	0.000	0.009	0.000	0.002	0.000	0.008	0.000	0.000	0.000	0.000	0.001
29	0.027	0.002	0.010	0.000	0.002	0.000	0.008	0.002	0.000	0.000	0.000	0.001
30	0.037	0.003	0.011	0.000	0.002	0.000	0.017	0.000	0.002	0.000	0.000	0.001
31	0.027	0.003	0.014	0.000	0.002	0.000	0.008	0.003	0.000	0.000	0.000	0.002
32	0.021	0.005	0.014	0.000	0.000	0.000	0.008	0.003	0.000	0.000	0.000	0.002
33	0.011	0.007	0.012	0.000	0.002	0.000	0.017	0.008	0.002	0.000	0.000	0.002
34	0.032	0.009	0.017	0.000	0.002	0.000	0.017	0.008	0.002	0.000	0.001	0.002
35	0.032	0.014	0.017	0.000	0.002	0.003	0.008	0.017	0.000	0.003	0.002	0.002
36	0.021	0.014	0.022	0.000	0.005	0.006	0.017	0.019	0.002	0.004	0.005	0.002
37	0.037	0.015	0.024	0.003	0.003	0.016	0.017	0.024	0.005	0.002	0.008	0.005
38	0.021	0.036	0.046	0.006	0.013	0.013	0.008	0.028	0.018	0.005	0.012	0.009
39	0.011	0.076	0.071	0.017	0.012	0.019	0.025	0.038	0.027	0.010	0.021	0.023
40	0.021	0.091	0.087	0.044	0.042	0.038	0.050	0.052	0.057	0.016	0.029	0.030
41	0.027	0.112	0.097	0.090	0.066	0.058	0.075	0.077	0.077	0.040	0.053	0.057
42	0.070	0.119	0.109	0.100	0.097	0.080	0.083	0.093	0.102	0.092	0.087	0.070
43	0.053	0.113	0.111	0.115	0.101	0.087	0.092	0.093	0.104	0.109	0.112	0.102
44	0.080	0.110	0.098	0.129	0.113	0.096	0.083	0.100	0.104	0.144	0.133	0.114
45	0.053	0.098	0.060	0.124	0.111	0.099	0.092	0.100	0.107	0.145	0.130	0.121
46	0.027	0.088	0.049	0.124	0.111	0.093	0.100	0.094	0.106	0.129	0.133	0.126
47	0.032	0.086	0.101	0.248	0.314	0.391	0.258	0.242	0.286	0.301	0.271	0.326
Sample size	187	582	1141	653	595	312	120	637	597	933	2046	1235

Table 10A-4. Dusky rockfish biomass estimates and standard errors from NMFS triennial/biennial trawl surveys in the Gulf of Alaska.

Year	1984	1987	1990	1993	1996	1999	2001	2003
Biomass	31068	94212	26827	57217	74480	49540	41905	70862
S.E.	7146	29391	8635	16590	32851	19193	11634	34352

Table 10A-5. Dusky rockfish trawl survey age compositions. Ages 4 and below are pooled. Pooled age 21+ includes all fish 21 and older.

Age (yr)	1984	1987	1990	1993	1996	1999	2001	2003
4	0.000	0.000	0.008	0.004	0.013	0.001	0.014	0.002
5	0.000	0.000	0.005	0.058	0.007	0.001	0.006	0.072
6	0.000	0.000	0.003	0.094	0.014	0.001	0.081	0.114
7	0.067	0.192	0.001	0.193	0.004	0.056	0.074	0.011
8	0.258	0.003	0.001	0.088	0.025	0.013	0.052	0.288
9	0.108	0.047	0.007	0.119	0.049	0.047	0.188	0.073
10	0.142	0.155	0.115	0.031	0.188	0.033	0.095	0.019
11	0.155	0.213	0.134	0.032	0.111	0.113	0.093	0.064
12	0.129	0.109	0.086	0.020	0.148	0.271	0.037	0.037
13	0.058	0.057	0.114	0.048	0.045	0.121	0.066	0.035
14	0.015	0.034	0.171	0.022	0.030	0.065	0.099	0.019
15	0.048	0.043	0.139	0.039	0.033	0.025	0.061	0.044
16	0.007	0.014	0.043	0.045	0.015	0.015	0.034	0.066
17	0.000	0.027	0.015	0.042	0.018	0.001	0.013	0.033
18	0.000	0.012	0.055	0.016	0.052	0.021	0.009	0.016
19	0.000	0.019	0.035	0.016	0.041	0.025	0.007	0.020
20	0.004	0.010	0.009	0.010	0.045	0.048	0.008	0.004
21+	0.010	0.065	0.061	0.123	0.165	0.146	0.062	0.083
Sample size	161	386	145	508	652	184	718	276

Table 10A-6. NMFS trawl survey length compositions for dusky rockfish. Fish 21 cm and less are pooled into length 21 and fish 47cm and greater are pooled. Survey size compositions are not used in model.

Length (cm)	1984	1987	1990	1993	1996	1999	2001	2003
21	0	0.002	0	0.005	0.003	0.001	0.007	0.001
22	0	0.001	0.008	0.002	0.002	0.001	0.002	0.004
23	0	0.001	0.004	0.004	0.004	0.001	0.003	0
24	0	0	0.002	0.007	0.003	0	0.005	0.001
25	0	0	0.006	0.002	0.003	0.002	0.003	0
26	0	0.001	0	0.015	0.001	0	0.004	0.004
27	0	0	0.007	0.018	0.001	0.001	0.006	0.017
28	0.002	0	0.006	0.023	0.001	0	0.002	0.024
29	0.001	0	0.007	0.021	0.005	0.001	0.022	0.027
30	0.004	0.002	0	0.03	0.002	0.002	0.024	0.044
31	0.009	0.001	0.001	0.039	0.002	0.006	0.029	0.027
32	0.014	0.005	0.007	0.051	0.002	0.008	0.033	0.031
33	0.016	0.002	0.001	0.043	0.007	0.008	0.026	0.053
34	0.037	0.018	0.003	0.04	0.003	0.013	0.03	0.008
35	0.051	0.041	0.001	0.046	0.006	0.015	0.026	0.011
36	0.07	0.066	0.002	0.053	0.001	0.015	0.042	0.013
37	0.066	0.1	0.004	0.037	0.009	0.016	0.039	0.043
38	0.092	0.089	0.006	0.048	0.009	0.019	0.04	0.077
39	0.129	0.079	0.019	0.051	0.016	0.016	0.059	0.072
40	0.136	0.108	0.017	0.051	0.036	0.03	0.061	0.066
41	0.129	0.139	0.077	0.035	0.08	0.035	0.071	0.050
42	0.101	0.114	0.125	0.044	0.065	0.075	0.06	0.050
43	0.061	0.109	0.115	0.061	0.127	0.103	0.064	0.065
44	0.036	0.059	0.153	0.064	0.133	0.114	0.058	0.070
45	0.021	0.027	0.175	0.073	0.111	0.15	0.083	0.065
46	0.012	0.018	0.151	0.065	0.113	0.141	0.076	0.062
47	0.014	0.019	0.104	0.075	0.256	0.231	0.127	0.114

Table 10A-7. Likelihoods and estimates of key parameters with estimates of standard error (σ) derived from Hessian matrix for 3 models for GOA dusky rockfish.

	Model 1		***Model 2***		***Model 3***	
Likelihoods	Value	Weight	Value	Weight	Value	Weight
Catch	0.02	100	0.40	10	0.48	10
Trawl Biomass	5.01	1	4.66	1	19.51	5
Fishery Ages	1.95	1	17.29	1	17.54	1
Survey Ages	58.48	1	63.74	1	64.80	1
Fishery Sizes	43.73	1	61.28	1	60.38	1
Data-Likelihood	**109.17**		**147.00**		**146.67**	
Penalties/Priors						
Recruitment Devs	14.46	1	14.95	1	16.99	1
Fishery Selectivity	1.38	1	0.98	1	0.95	1
Trawl Selectivity	0.86	1	0.51	1	0.61	1
Fish-Sel Domeshape	0.00	1	0.00	1	0.00	1
Survey-Sel Domeshape	0.01	1	0.00	1	0.00	1
F Regularity	5.80	0.1	6.24	0.1	5.83	0.1
σ_r prior	5.01		4.85		4.22	
q-prior	0.39		0.00		0.11	
Total	80.08		83.68		81.13	
Objective Fun. Total (unweighted)	***189.25***		***230.68***		***227.80***	

Parameter Estimates	Value	σ			Value	σ
q-trawl	0.673	0.175	0.962	0.177	0.811	0.135
σ_r	1.087	0.131	1.094	0.131	1.127	0.131
Log-mean-rec	1.228	0.287	1.053	0.214	1.202	0.211
F_{40}	0.123	0.026	0.120	0.025	0.120	0.025
Total Biomass (mt)	48,037	20,958	38,658	14,341	58,519	15,092
B_{2004} (mt)	16,985	7,899	11,563	4.427	17,766	4,660
B_0 (mt)	36,029		28,642		35,749	
B_{40} (mt)	14,412		11,457		14,300	
ABC_{F40} (mt)	3,766		2,430		**4,056**	
F_{50}	0.082	0.017	0.081	0.016	0.080	0.016
ABC_{F50} (mt)	2512		1628		2719	

Table 10A-8. Set of projections of spawning biomass (SB), fishing mortality and yield for dusky rockfish in the Gulf of Alaska. This set of projections encompasses six harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). For a description of scenarios see Model Projections section. $B_{40\%}$ = 14,300 mt, $B_{35\%}$ = 12,512 mt, $F_{40\%}$ = 0.120, and $F_{35\%}$ = 0.148.

Year	Maximum permissible F	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
			Spawning biomass (mt)			
2004	17,313	17,313	17,313	17,313	17,313	17,313
2005	17,126	17,273	17,214	17,422	17,057	17,126
2006	16,427	17,377	16,991	18,392	15,998	16,427
2007	15,807	17,477	16,788	19,360	15,083	15,741
2008	15,122	17,438	16,468	20,195	14,160	14,710
2009	14,511	17,369	16,154	20,951	13,403	13,834
2010	13,924	17,225	15,797	21,588	12,777	13,089
2011	13,529	17,138	15,531	22,221	12,382	12,607
2012	13,334	17,125	15,382	22,833	12,207	12,370
2013	13,332	17,243	15,387	23,519	12,224	12,342
2014	13,408	17,403	15,455	24,184	12,311	12,395
2015	13,558	17,641	15,604	24,912	12,459	12,519
2016	13,753	17,944	15,816	25,709	12,639	12,681
2017	13,917	18,205	15,999	26,411	12,784	12,813
			Fishing mortality			
2004	0.074	0.074	0.074	0.074	0.074	0.074
2005	0.120	0.060	0.084	-	0.148	0.120
2006	0.120	0.060	0.084	-	0.148	0.120
2007	0.120	0.060	0.084	-	0.148	0.148
2008	0.120	0.060	0.084	-	0.146	0.148
2009	0.119	0.060	0.084	-	0.138	0.143
2010	0.115	0.060	0.084	-	0.131	0.135
2011	0.111	0.060	0.084	-	0.127	0.129
2012	0.109	0.060	0.084	-	0.124	0.126
2013	0.108	0.060	0.084	-	0.124	0.125
2014	0.107	0.060	0.084	-	0.124	0.125
2015	0.107	0.060	0.084	-	0.125	0.125
2016	0.108	0.060	0.084	-	0.126	0.126
2017	0.109	0.060	0.084	-	0.127	0.127
			Yield (mt)			
2004	2,651	2,651	2,651	2,651	2,651	2,651
2005	4,056	2,083	2,881	-	4,956	4,056
2006	3,918	2,114	2,867	-	4,676	3,918

2007	3,985	2,245	2,992	-	4,662	4,866
2008	3,687	2,171	2,842	-	4,172	4,394
2009	3,608	2,207	2,849	-	3,840	4,077
2010	3,268	2,144	2,727	-	3,403	3,563
2011	2,942	2,051	2,571	-	3,044	3,151
2012	2,794	2,014	2,501	-	2,904	2,977
2013	2,857	2,068	2,559	-	3,005	3,056
2014	2,922	2,114	2,609	-	3,099	3,134
2015	2,992	2,155	2,656	-	3,190	3,215
2016	3,075	2,201	2,709	-	3,291	3,308
2017	3,139	2,240	2,751	-	3,364	3,376

Table 10A-9. Allocation of 2005 ABC for dusky rockfish in the Gulf of Alaska. Apportionment is based on the weighted average of pelagic shelf rockfish assemblage biomass estimates in last three trawl surveys.

Year	Weights	Western Gulf	Central Gulf	Eastern Gulf	Total
1999	4	7%	66%	26%	100%
2001	6	13%	57%	31%	100%
2003	9	6%	75%	19%	100%
Weighted Mean	19	8%	67%	24%	100%
Area Allocation		8%	67%	24%	100%
Area ABC (mt)		**336**	**2,732**	**988**	**4,056**
OFL (mt)		**416**	**3,379**	**1,223**	**5,018**

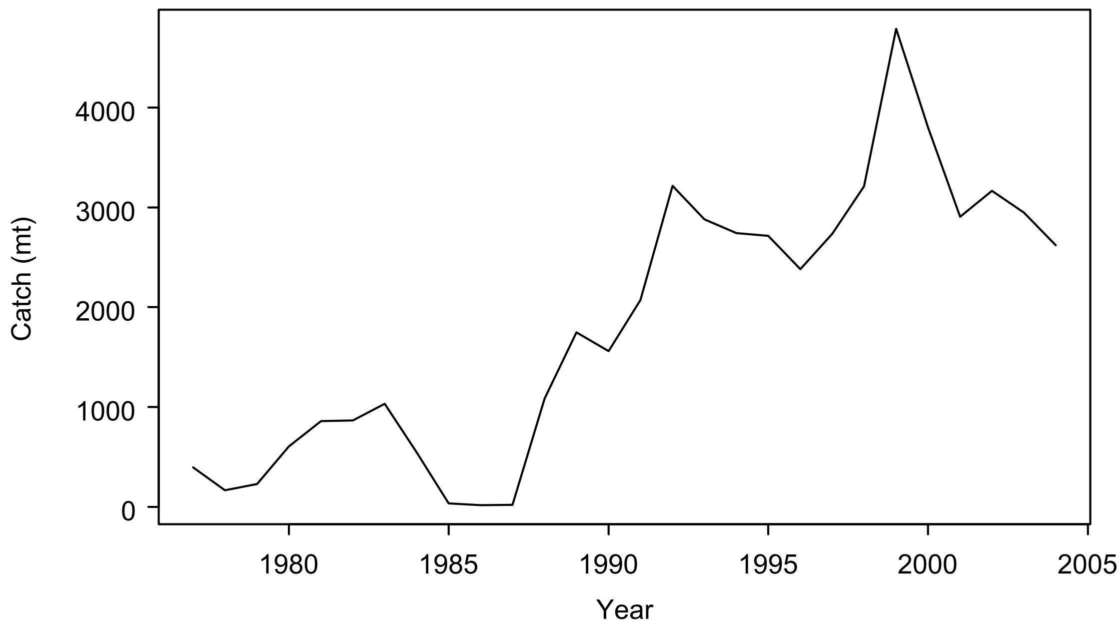

Figure 10A-1. Estimated commercial catches for Gulf of Alaska dusky rockfish.

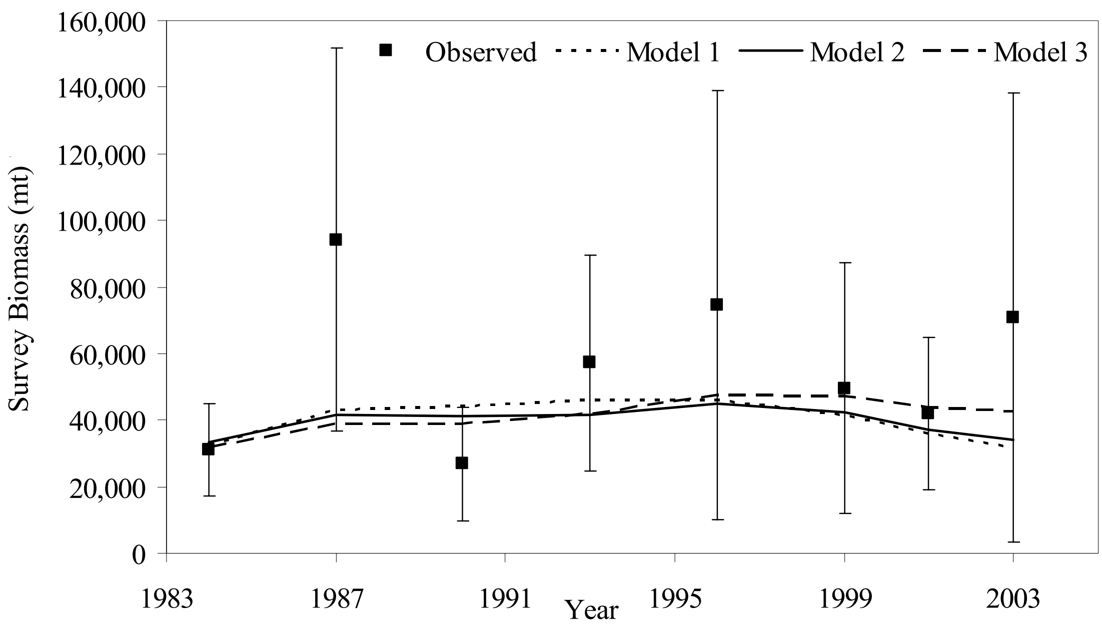

Figure 10A-2. Observed and predicted GOA dusky rockfish trawl survey biomass based on the three models. Observed biomass=squares with 95% confidence intervals of sampling error.

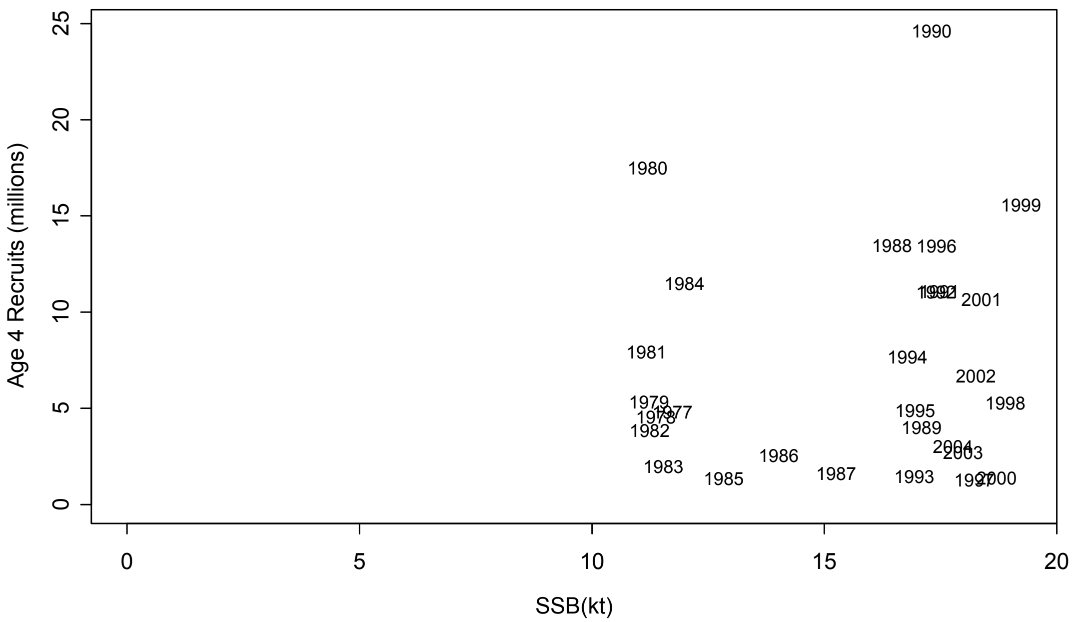

Figure 10A-3. Scatterplot of spawner-recruit data for GOA dusky rockfish estimated from Model 3. Label is year class of age 4 recruits. SSB = Spawning stock biomass.

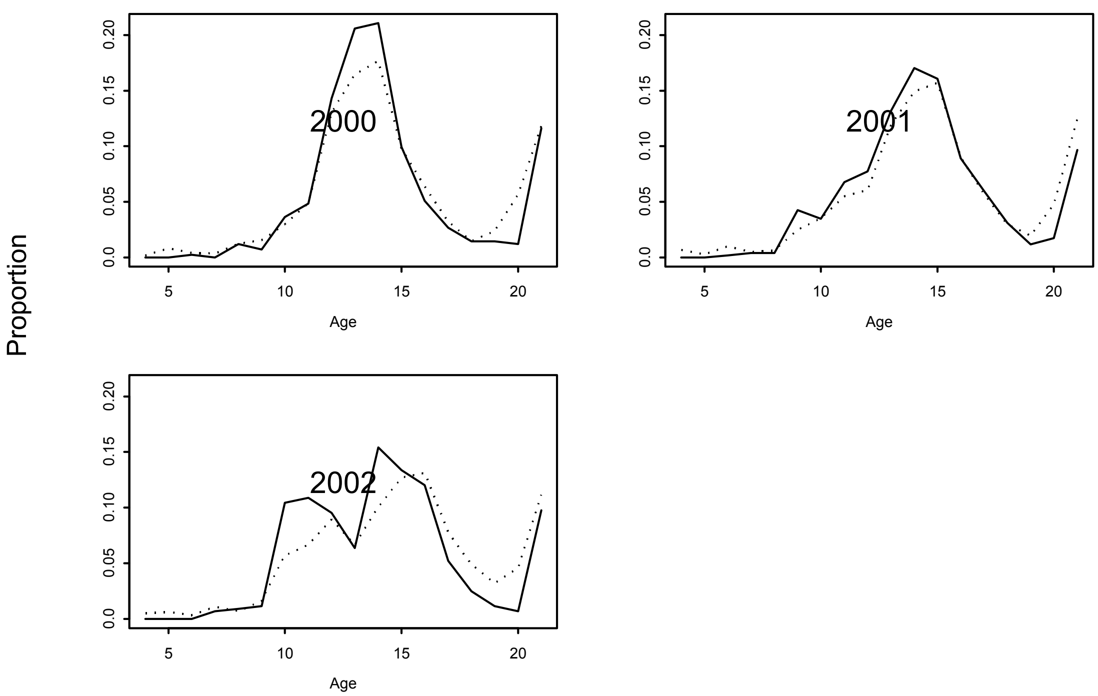

Figure 10A-4. Fishery ages for GOA dusky rockfish. Observed=solid line, predicted for Model 3=dotted line.

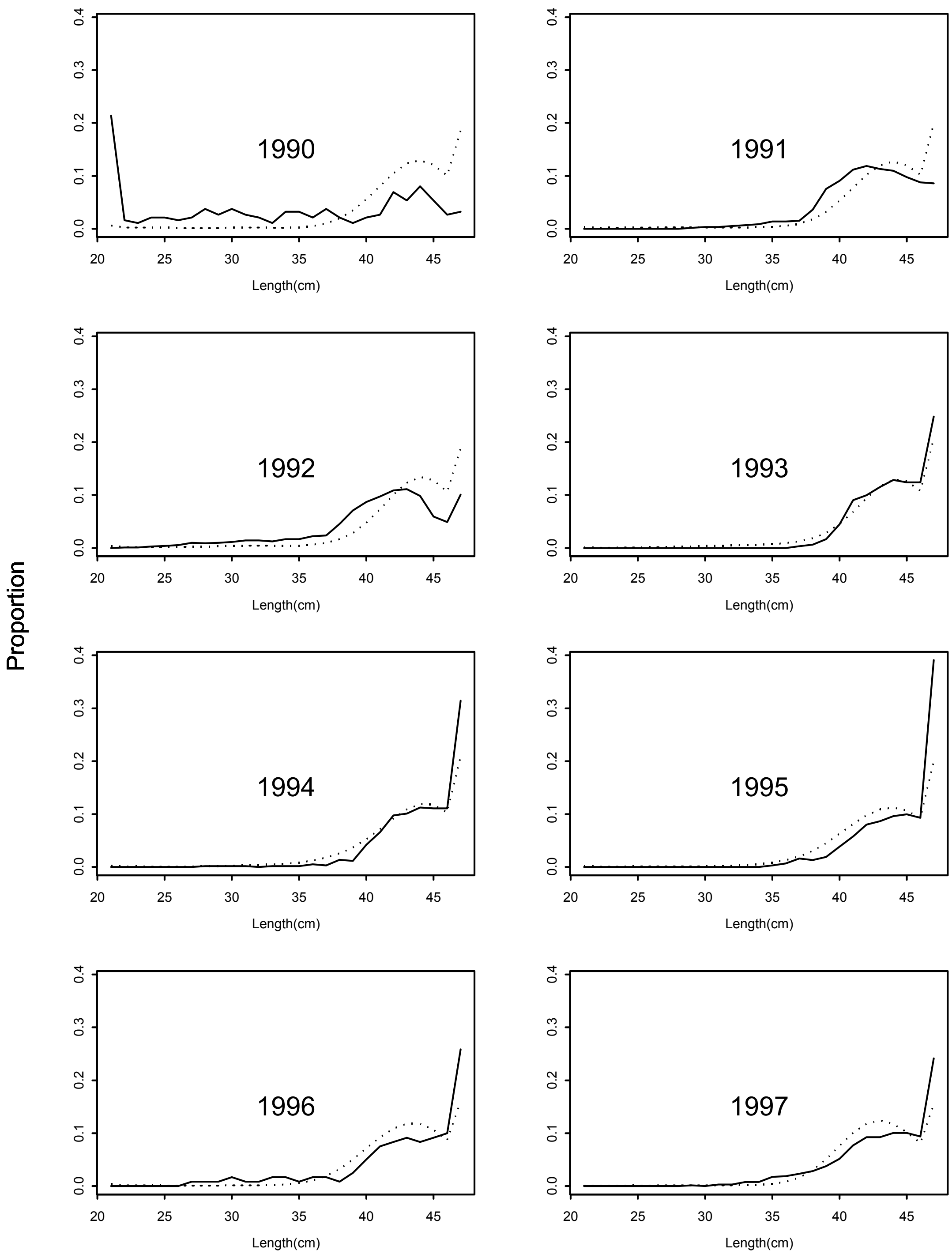

Figure 10A-5. Fishery length compositions for GOA dusky rockfish for base model. Observed=solid line, predicted for Model 3=dotted line.

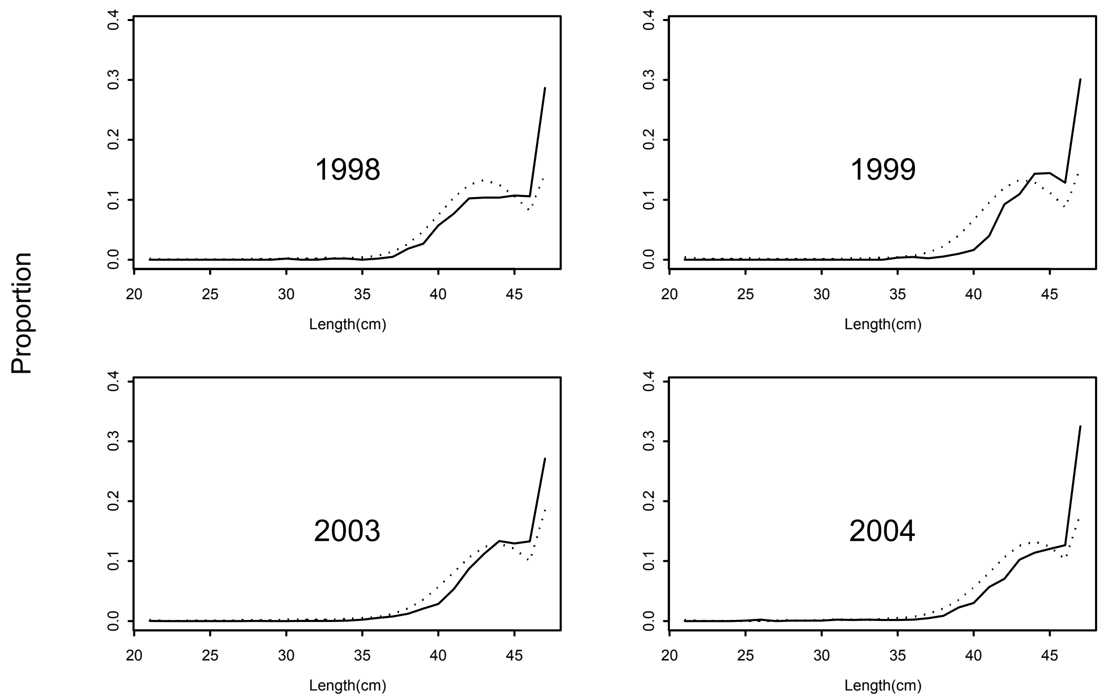

Figure 10A-5 (continued). Fishery length compositions for GOA dusky rockfish. Observed=solid line, predicted for Model 3=dotted line.

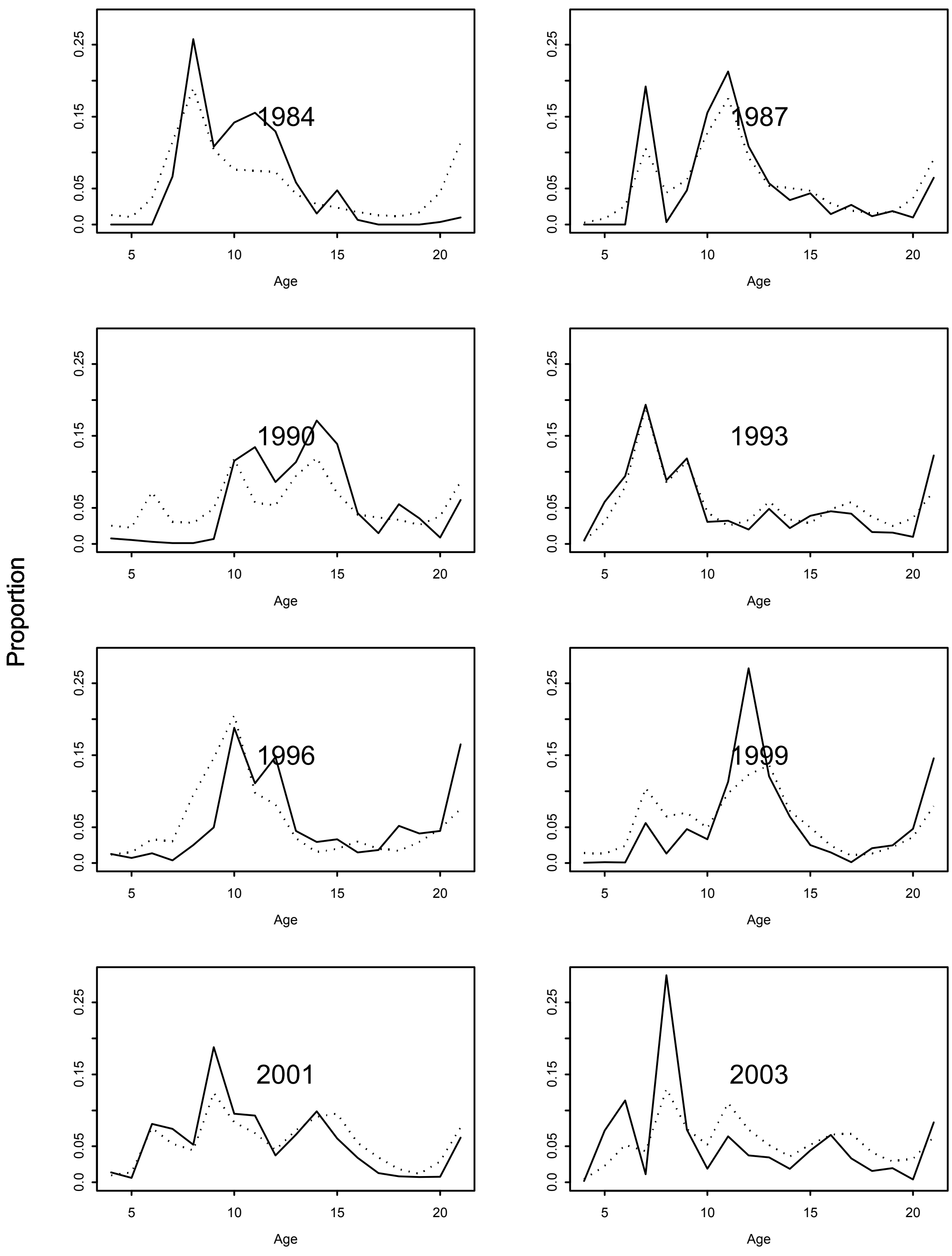

Figure 10A-6. Trawl survey age composition by year for GOA dusky rockfish. Observed=solid line, predicted for Model 3=dotted line.

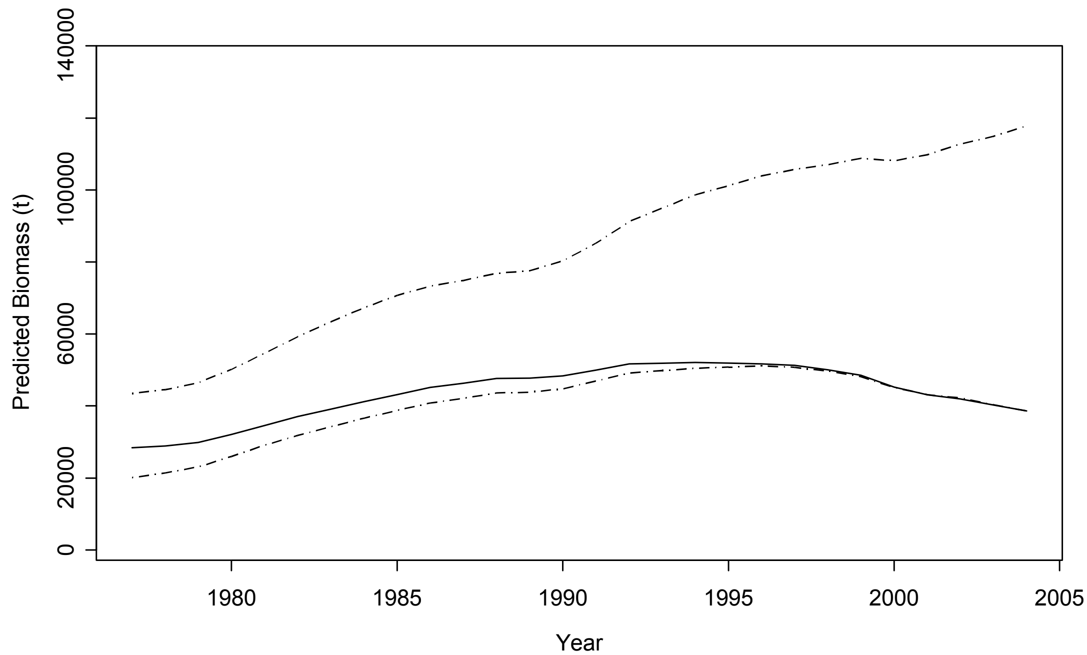

Figure 10A-7. Time series of predicted total biomass for Model 2. Dashed lines represent 95% confidence intervals from 5 million MCMC runs.

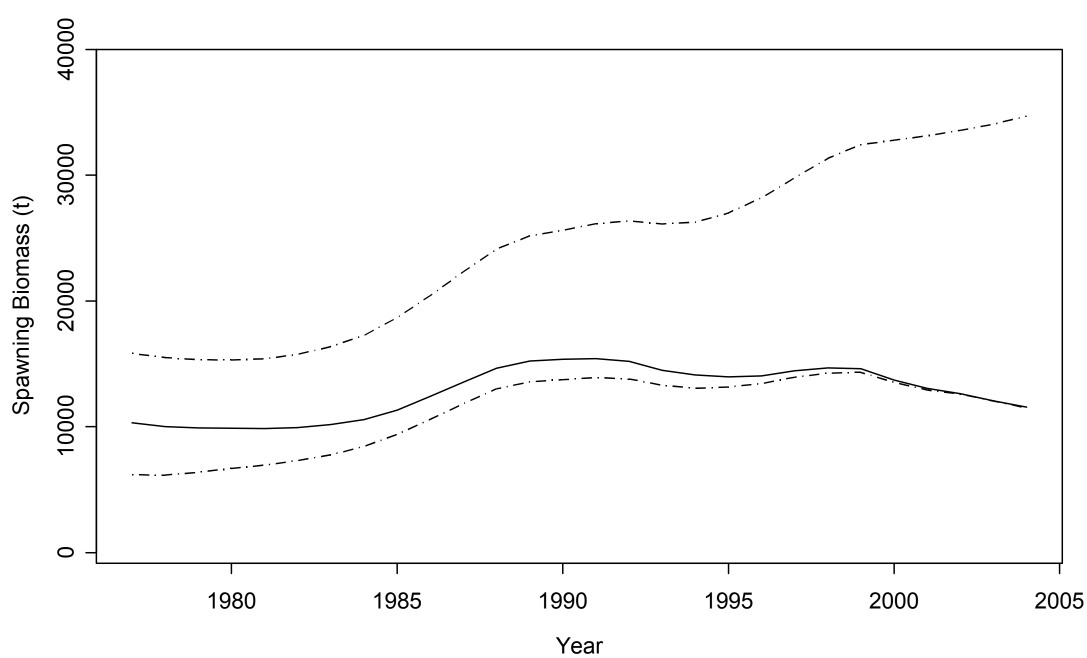

Figure 10A-8. Time series of predicted spawning biomass of GOA dusky rockfish for Model 2. Dashed lines represent 95% confidence intervals from 5 million MCMC runs.

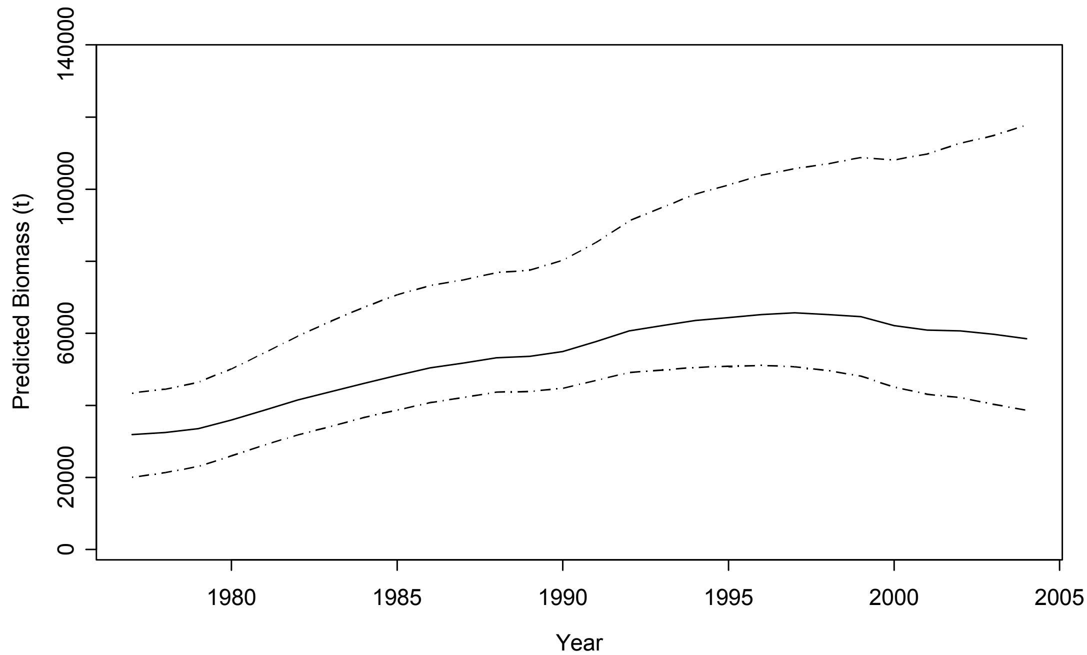

Figure 10A-9. Time series of predicted total biomass for Model 3. Dashed lines represent 95% confidence intervals from 5 million MCMC runs.

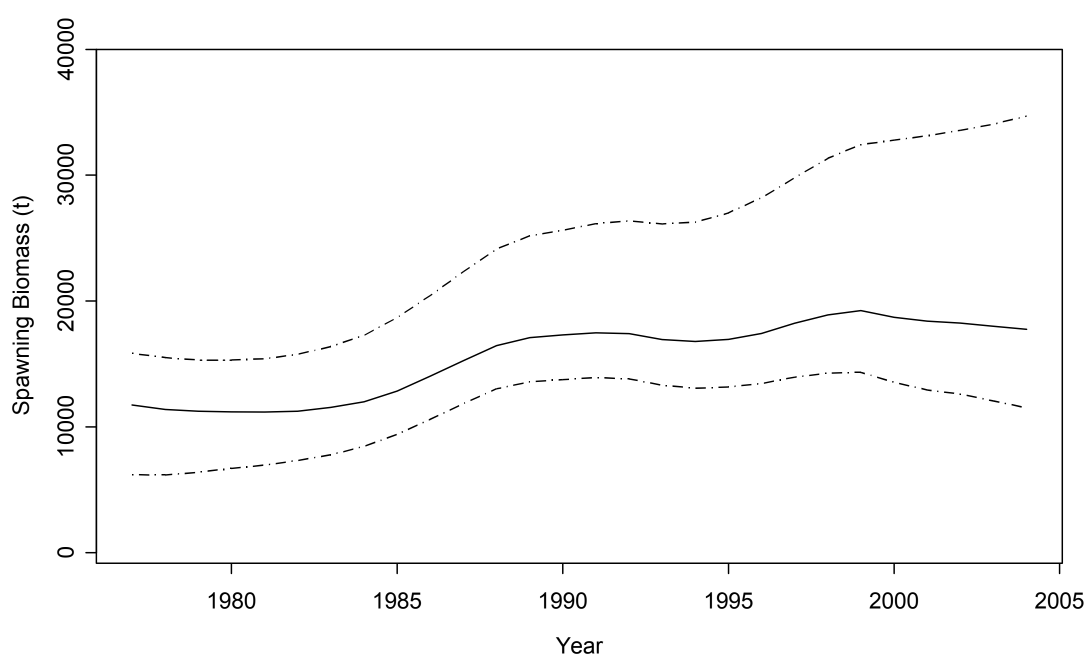

Figure 10A-10. Time series of predicted spawning biomass of GOA dusky rockfish for Model 3. Dashed lines represent 95% confidence intervals from 5 million MCMC runs.

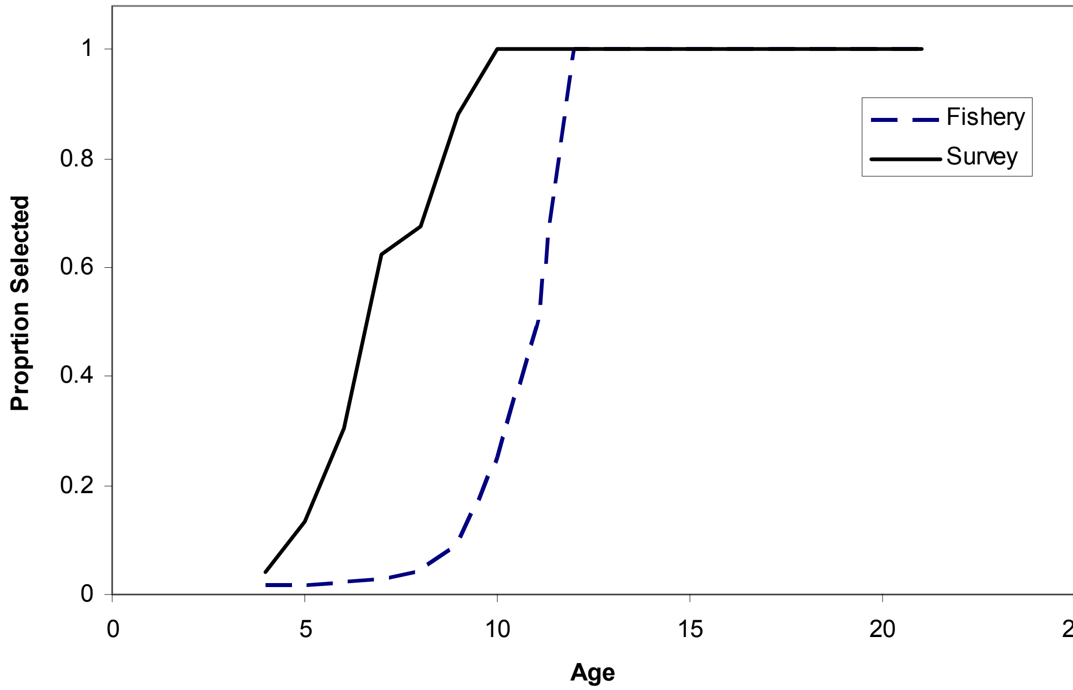

Figure 10A-11. Estimated fishery and survey selectivity for Model 3 for dusky rockfish. Dashed line is fishery selectivity and solid line is survey selectivity.

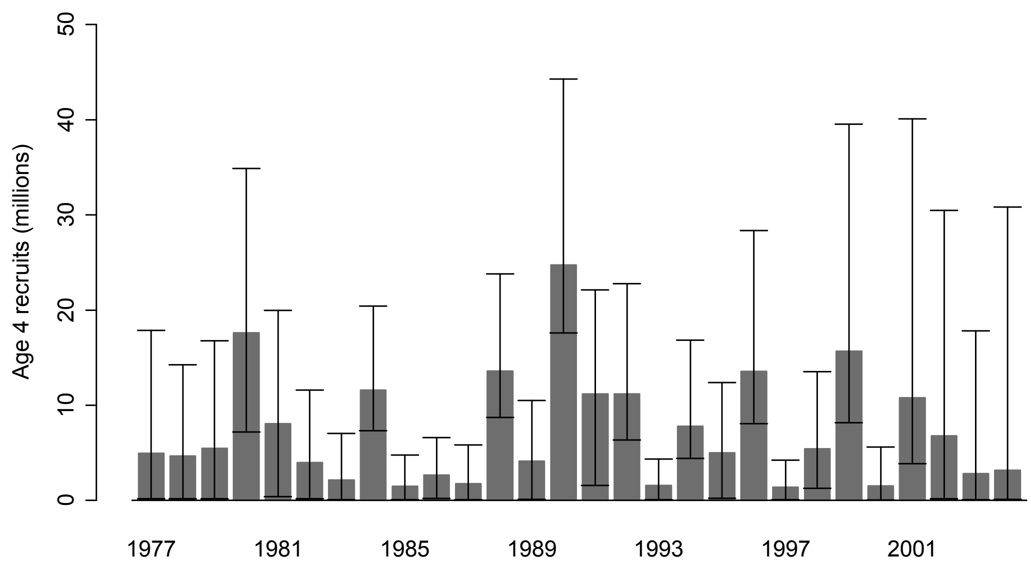

Figure 10A-12. Estimated recruitments (age 4) for GOA dusky rockfish from Model 3.

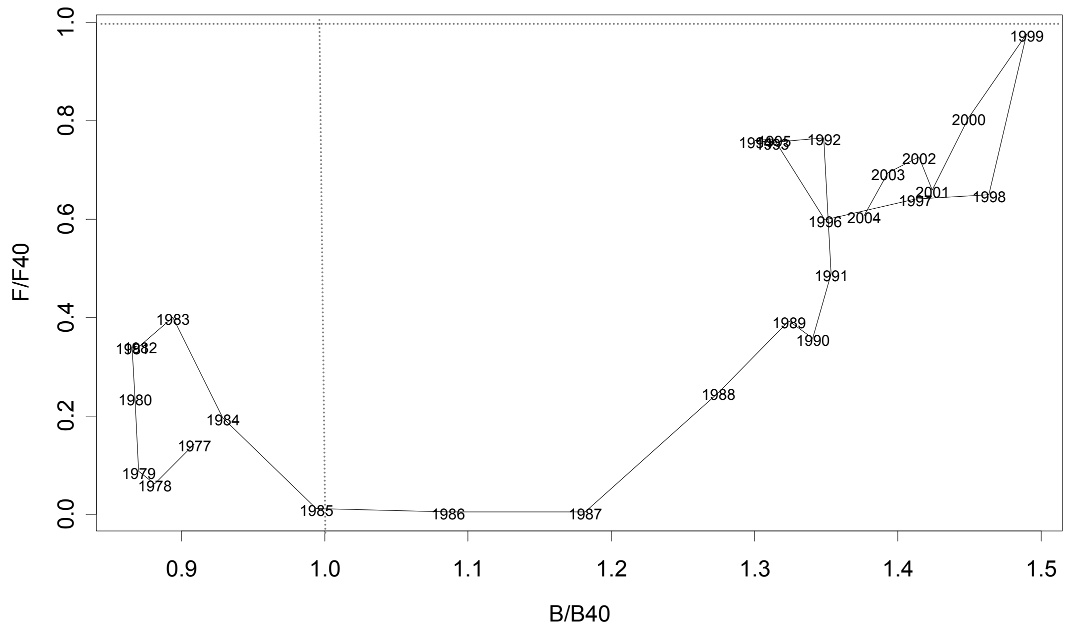

Figure 10A-13. Time series of estimated fishing mortality over $F_{40\%}$ versus estimated spawning biomass over $B_{40\%}$ for Model 3.

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